Survey based behavior and impact assessment A case study of improved cookstove adoption in rural Honduras

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Abstract

Nearly 40% of the world's population relies on inefficient burning of biomass using traditional stoves and open fires for their household energy demands. Use of traditional methods contributes to global anthropogenic climate change, and has been attributed to at least 4 million premature deaths every year. In addition, increasing population in middle- and low- income countries pushes the demand for firewood to unsustainable harvest rates leading to deforestation. To address such challenges, many international organizations have worked to provide improved cookstoves for these communities. This study applies surveys incorporating research methods from social sciences focusing on the role of users to evaluate the impacts of these technologies in the field, as well as to understand what motivates consumers to change their traditional practices. By conducting surveys before and two months after dissemination of 390 improved cookstoves in Copan Ruinas, Honduras, this research evaluated the impact of the improved cookstoves for the users and their evaluations of the presented technology. Results suggest that approximately 85% of the households used the improved cookstove as their primary stove. The top three reasons for households to continue using the stove were reported as reductions in smoke emissions, firewood consumption, and time to cook food. For 80% of the households, the level of effort required to cook with the improved cookstove was reported as significantly less than traditional stove. Future work should include sensor-based monitoring and long-term follow up to verify findings and examine impact over time.

Keywords— Behavior assessment, technology adoption, design for development, improved cookstoves

I. INTRODUCTION

Traditional open fire cooking has a multitude of negative consequences on livelihoods for households in rural developing communities such as public health issues, increasing scarcity of fuel, and contributions to climate change. For 2.7 billion of the world's population, firewood is the primary source of energy and can meet more than 90% of a households' energy needs for cooking and heating [1][2]. According to the 2010 Global Burden of Disease, household air pollution (HAP) from this practice contributes to 3.5-4 million premature deaths every year [3][4]. Solid fuel combustion can contribute to deforestation and forest degradation as well, with 27-34% of the annual global firewood harvest being reported as unsustainable [5][6]. Global contributions to climate change due to such practices are also significant, as recent estimates show 34 – 45% of the warming due to black carbon is generated by traditional biomass combustion[6]–[9].

To address these challenges, improved cookstoves such as the Ecocina (Figure 1) developed by StoveTeam International have been disseminated for several decades. These small renewable energy technologies seek to increase both heat transfer and combustion efficiency of biomass combustion, reducing the emission of toxic chemicals and consuming less firewood to complete the same cooking tasks. In addition, improved cookstoves can provide households with higher safety and less time required for collecting firewood and tending the fire.

While multiple studies have applied sensor- or survey- based approaches to measure in-field improved cookstove performance, evaluation of motivation and impacts from the user's viewpoint present significant room for improvement. Sensor-based measurements can be divided into three categories including air pollution monitoring [10], stove body temperature logging as a proxy for use [11], and fuelwood usage monitoring [12][13]. Survey-based evaluations vary by sample sizes and hypotheses. Lewis and Pattanayak [14] reviewed empirical studies related to improved cookstove adoption and conclude that extensive contextual attributes should be studied to ensure successful stove adoption. Following this recommendation, this study incorporates a systematic survey-based approach to evaluate improved cookstove performance and adoption using an integrated and comprehensive survey based on previous empirical studies conducted by StoveTeam International. These

Fig. 1. The Ecocina by StoveTeam International

previous studies were based on recommendations and practices of Winrock International, Berkeley Air Monitoring Group, and the Global Alliance for Clean Cookstoves.

The goal of this study was to evaluate the adoption and impacts of these types of cookstoves in rural communities, and to better understand the motivation for consumers to adopt them. In 2017, with funding support from the Portland Oregon chapter of the non-profit Dining for Women, StoveTeam International distributed 390 locally manufactured Ecocina cookstoves in eight rural villages in Copan Ruinas, Honduras. In conjunction with the provision of the cookstoves, a series of two surveys were used before and after to evaluate the drivers of stove adoption and its impact on the livelihood of the participating households. The baseline values of study variables were measured in each household shortly before provision of the cookstoves, followed by a follow-up survey two months later that included several questions similar to the baseline, as well as questions related to the respondents' experience with Ecocina. The changes in the variables from baseline to follow-up are used to assess the impact of the technology on the households.

II. Background

Despite the potential positive impacts of using improved biomass cookstoves, successful user adoption of improved cookstove can be a challenge because the technology must be in harmony with the users' perspectives and needs. Multiple studies have discussed the importance of user behavior on improved cookstoves' adoption [14]–[16]. Households in low resource settings by nature are faced with a number of competing challenges and it is therefore necessary to formulate the cookstove design and dissemination strategy based on households' priorities.

Recognition of the various household priorities and reflecting them into design and implementation of improved cookstove was addressed in a study in rural Bangladesh [17]. Results indicated that households do not consider indoor air pollution as an important issue, and the authors suggested that cookstoves with features that users value, such as less fuelwood consumption or any cost saving attribute, could help to alleviate low adoption rates. Another study in rural regions of northern India obtained preferences of more than 2,000 households and concluded that widespread adoption of improved cookstoves was not likely in the area due to supply-side challenges in providing applicable alternatives to traditional stoves, and that users perceived their benefits by both the technology and promotion messages [18]. The authors suggested that user preferences must be applied to develop more effective policies.

User's preferences and values are reflected through behavior. Therefore, a better understanding of user behavior could inform the designers and project implementers about best approaches for technology design and dissemination. The impact of user behavior on successful technology adoption was recognized in a four-year study in a rural region in India by Hanna, Duflo, and Greenstone [19]. The long-term results indicated that even though the performance of the introduced technology was effective in laboratory tests, low stove valuation by users precluded improvements in health or firewood consumption. Their study concluded that if users decide not to use the stove regularly and properly, avoid regular maintenance, or do not update their beliefs about how to use it, the health and fuel saving impacts may not be achieved.

To capture both the user experience with the cookstoves as well as their attitudes and behaviors regarding cookstove adoption, the surveys developed for this study have two sections. The present report is focused on the first section of the surveys exploring the user's demographic information and assessment of their experiences with the cookstoves. The second section is focused on a systematic method to evaluate user behavior through application of theory of planned behavior (TPB)[20]. TPB is among the most frequently applied methodologies in the field of health behavior and environmental psychology [21]–[23]. This theory explains user behavior in terms of making an environmentally friendly and health related decision based on individual attitudes and beliefs, social norms, and ability to control behavior. Results of the TPB analysis are integrated into a holistic study of cross cultural behavior assessment [24].

III. Methodology

This study developed and implemented before-and-after surveys that capture user experiences and stove performance evaluations to provide insights for understanding user perceptions in regard to adoption of improved cookstoves.

A. Stove type

The stove evaluated in this project was the Ecocina insulated ferro-cement rocket stove developed by Dr. Larry Winiarski and Nancy Hughes. It can be operated with either a cooking pot or comal (a round flat griddle made of metal or clay) for cooking tortillas, and use of a pot skirt can further increase efficiency. Similar to other well-designed rocket stoves, the Ecocina has been shown to produce roughly one-third of carbon monoxide and particulate matter compared to the open fire in laboratory tests and save approximately 30% of fuel [25]. The stoves distributed in this study were locally manufactured at the E'Copan Stove Factory supported by

StoveTeam International. Local manufacturing of the stove can help to provide jobs, reduce costs, and improve quality of maintenance and customer service to support long term stove adoption.

B. Study Design

This study was conducted in collaboration between Oregon State University's Humanitarian Engineering Program and StoveTeam International with in-field support from the E'Copan Stove Factory. StoveTeam facilitated the communication between researchers and the field partners and supervised the data collection projects. Overall, 379 households participated in the surveys. These households were identified by the local partner through demographic and census review, information campaigns and advertisements.

This project was carried out in three phases: pilot, baseline, and follow-up. First, in January 2017 a pilot study was conducted with a randomly selected sample of 10 households in the community. This pilot survey incorporated seven open-ended questions to inform researchers about dominant beliefs of the target community to develop the questions in the way that complied with widespread beliefs. The results of the pilot suggested that firewood consumption, cleanness of the kitchen and cooking time were among the most important attributes valued by households in the community. Thus, questions were designed to ask household opinions based on time, emissions, and firewood consumption, enabling ranking of the attributes with respect to community's priorities rather than the researchers' interests. This is necessary for the behavior research to evaluate the proper beliefs in each context [26]. For example, a researcher may be inclined to ask questions regarding indoor air pollution. However, if this is not a priority for this set of users, the researcher will be unable to capture the real user evaluations. Asking the user evaluations based on a user's priorities however will reflect the user's dominant beliefs and be more likely to explain the actual behaviors.

In the second phase, a baseline survey was implemented to measure the status quo. The questions intended to draw out households' experiences with traditional stoves and their impacts on livelihood, as well as expectations regarding an improved cookstove. The baseline survey was implemented in February 2017 and the field partner began to distribute Ecocinas to the participants at the same time. In the third phase, the follow-up data collection was conducted in April 2017. The purpose of follow-up study was to re-measure many attributes for improving the validity of responses, and to evaluate user experiences, uptake, and impacts of Ecocina.

Both baseline and follow-up surveys were carried out from an identical sample size of 379 households. A variety of variables were incorporated in the surveys to capture many aspects of cookstove adoption such as direct stove experience, health, and social networks (Table I). Some topics are included in both surveys to determine if a respondent's answers change after her experience of cooking with the Ecocina. In some cases, asking particular questions before and after intervention can quantify the Ecocina's impact. Conducting test-re-test method this research improves the reliability of responses [26]. This means asking questions two times or more over a period to avoid short-term biases affecting respondents indirectly.

Although asking users about their opinions and experiences provides insight into cookstove adoption and impact, self-reporting methods are prone to biases such as recall bias, social

TABLE I. SURVEY QUESTIONS' TOPIMPROVED COOKSTOVE AND TYPES OF QUESTIONS

	Section	**Number of question** (B)-baseline (F)-follow-up	**Type of questions**
1	Participant Identification	9 (B) + 9 (F)	Open ended
2	Stove use pattern	24 (B) + 21 (F)	Multiple choice/open ended
3	Fuel procurement	17 (B)	Multiple choice/open ended
4	Household demographic information	22 (B)	Multiple choice/open ended
5	Theory of planned behavior	34 (B) + 28 (F)	Multiple choice/open ended
6	Social network	6 (B) + 3 (F)	Open ended
7	Health and safety	28 (B) + 29 (F)	Multiple choice
8	Stove and kitchen area observation	6 (F)	Multiple choice/open ended
9	Cooking dynamimproved cookstove	7 (F)	Multiple choice
10	Fuel procurement	16 (F)	Multiple choice/open ended
11	Income generating impacts	4 (F)	Multiple choice
12	Perception of the Ecocina	10 (F)	Multiple choice/open ended

TABLE II. DEMOGRAPHIC INFORMATION OF THE SAMPLE

Sample size	379
Number of villages	8
Affected Population by gender	Female: 892 (51%) Male: 873 (49%) Total: 1765
Number of children (under 17)	Female: 353 (52%) Male: 331 (48%) Total: 684
Main cook's age distribution	Minimum: 15 Maximum: 94 Average: 37.4 Std. dev.: 14.5
Income average	770 HNL Std. dev.: 895 HNL
Education (Primary income earner)	No education: 70% Incomplete primary education: 30%

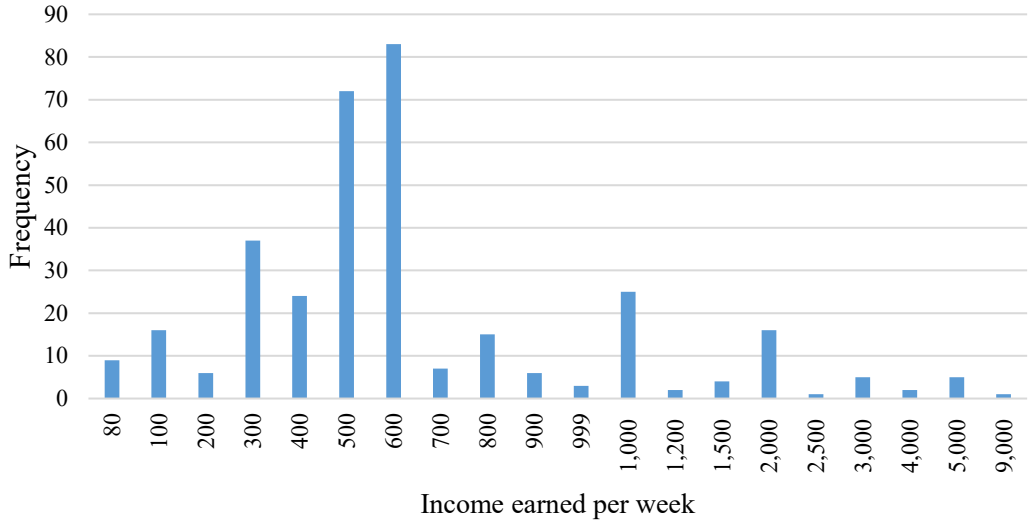

Fig. 2. Distribution of stated income earned by main income earner per week in winter (HNL)

desirability bias, or the Hawthorne effect [27]. These refer to situations in which a participant does not clearly recall precise values or expresses the opinion that they think is socially desirable or pleasant for the surveyor. In other cases the respondent's behavior may not be representative of their actual beliefs due to the process of being observed by someone else [28]. Some statistical techniques to recognize and alleviate the impact of self-report biases are presented by Mortel [29]. However, a better approach is to validate reported impacts through quantitative and objective methods such as sensor based monitoring [13][29] [30]. With these methods, data elicited from surveys can be coupled with sensor data to more holistically inform technology designers and implementers about the performance and impact of their projects. Development of these methods is underway [12].

IV. Results

In addition to demographic details, the study's major findings in, health and safety, stove experience, and social impacts are presented in this section.

A. Demographic Information

Results of the surveys showed that the cookstoves distribution has directly impacted at least 1,765 individuals, 84 of which (39%) are children under the age of 17. Additional demographic information is presented in Table II. The income distribution of household heads are illustrated in Figure 2.

In the sample, 19% of the participants had a functioning refrigerator and 67% of them had cell phones. Results showed that 66% of female heads of the family are able to read and write. Nearly 80% of the children attend school every day it is in session. In addition, 86% of the respondents mentioned sickness as the reason that causes students to miss 5 days or less of school, with only 1% or less reporting staying home to help with chores or earning income.

B. Stove experience

The participating households in this study received an Ecocina cookstove after or at the time of the baseline survey. Households were not asked to provide any type of payment or support toward installation of the stoves. Obtaining stoves at the time of baseline study provided them with approximately two months of opportunity to experience cooking with a new device in advance of the follow-up survey that elicited their experiences. In the baseline, 97% of respondents mentioned the traditional plancha (a large flat metal griddle held above a fire) as their primary stove (and at least 50% or more reported cooking each of their staple foods including tortillas, beans, rice, meat, and coffee/tea on it) and only 10% of the sample had another stove choice. Only 2 households reported use of LPG as a primary stove and 6 as their secondary stove. Households reported fast cooking, cooking of multiple dishes simultaneously, and conserving heat/getting very hot as the favorite aspects (in order) of their current primary cooking method. The worst aspect identified by far was producing too much smoke. Approximately 32%, 24%, 38%, 61%, and 88% reported using their current stove for additional services such as insect repellant, lighting, making animal feed, warming bath water, and making medicine, respectively, in addition to typical cooking processes. Only 2.9% report using open fires or other biomass devices for a business.

The households reported that the husband is responsible for fuelwood collection in 64% of households, followed other (8.7%), self (8%), male children (7.6%), and female children (0.29%). Of fuelwood collecting households, 67% do so daily and 20% do so weekly, while the majority (69%) do so on foot and the rest use a horse or mule with packs. Typically this is done at the same time as other chores in 24.7% of households and takes an average of 3.0 hours (standard deviation of 2.7 hours). Fuelwood is stored outside in 61% of households, inside in 32%, and by the stove in 6% of homes. Approximately 28% of households report challenges with the fuel getting wet, 14% that it is difficult to access, and only 3% that it might get stolen.

At the time of the baseline survey, only 14% of households report purchasing wood. Those who purchase report an average cost of 1462 HNL (standard deviation of 1,944) per trip.

In the follow-up visit, the Ecocina was observed to be in usable condition in nearly 90% of the houses. In more than 80% of the households Ecocina was either alight or had signs of recent use by the time of the surveyor's visit. For 85% of the respondents, Ecocina was the primary stove at the time of follow-up survey. This may be somewhat over-reported as only 73% reported using the Ecocina at least once per week, and 59% using it 7 days per week. The traditional plancha was still present in 30% of households, and 60% of households reporting using a single stove and 37% reporting using two stoves each week. For the primary stove, 75% reported using it for 3 meals per day and 18% for two. As a whole, 25% of households reported using two stoves at the same time on occasion, typically (68%) three times or less per week, to cook two dishes at the same time (80%), when in a rush (8%), or when cooking for large numbers (5%). Between 85% and 87% of respondents selected the Ecocina as the stove they use to cook each of their staple dishes including tortillas, beans, rice, tamales/tomalitos, nixtamal, and hot drinks. The overall number of people who purchase

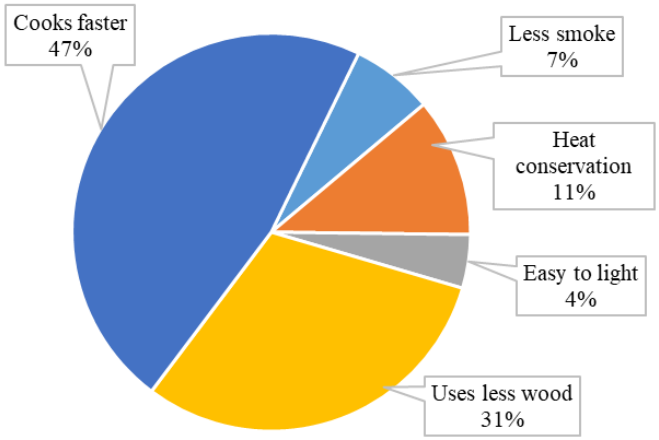

Fig. 3. Stated benefits of using Ecocina.

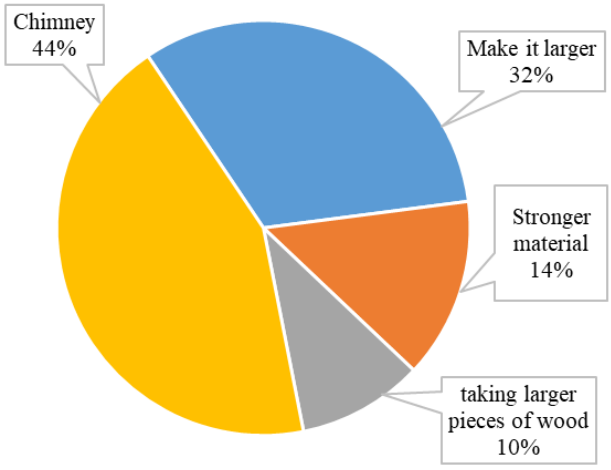

Fig. 4. Stated potential improvements to the Ecocina.

fuelwood reduced from 14% of respondents at baseline to 7% of respondents at the follow-up. In addition, the average spending on fuel dropped from 1462 HNL at baseline to 823 HNL in follow-up. The use of multiple stoves at early stages is normal due to gradual process of clean technology uptake. However continued stove stacking could be the result of factors that could be addressed through an integrated design approach that holistically captures users' needs, behaviors, cultural dimensions and priorities [32].

The considerable up-take of the Ecocina is likely to be the result of multiple improvements that households perceived. First, 80% of the respondents mentioned that cooking with Ecocina requires less time than before. Households' stated activities that they spent the time they saved by cooking faster using Ecocina are 74% cleaning house/domestic tasks, 12% leisure, 6% working in the field, 4% helping children with school and 4% taking care of children. Second, for 80% of the households the level of efforts required for cooking such as fuel preparation, lighting the fire, tending it, and managing the food was significantly less than before when they cook with Ecocina. Third, 95% of the households claim that since they received Ecocina they use less firewood than before. The surveyors asked respondents to show them a rough comparison of the amount of firewood they used to consume before adopting Ecocina and afterward. Surveyors' estimated firewood savings suggest that 52% of households used ½ less, 24% used ¼ less, and 23% used ¾ less firewood. The weighted average of the surveyors' estimates indicates 37% less firewood is consumed in follow-up compared to baseline. Less consumption of firewood could lead to less firewood collection effort and less time for the firewood harvest trips. On average the time that households spent to collect wood was reduced by 11.3%.

The survey also asked households direct questions regarding what they liked and what they think needs to be improved about the Ecocina. Over 98% of users reported the Ecocina as very easy (93%) or somewhat easy (5%) to use, and all but 1 respondent believed it was equally (13%) or more safe (87%) than their traditional method. Based on the responses presented in Figure 3, faster cooking practice and less fuelwood consumption are the most frequently chosen responses regarding what they liked about the Ecocina. Whereas in Figure 4 respondents suggest that adding chimney, material issues, and size of the stove have room for further improvements.

C. Health and safety

This study asked households about any health-related issues they had in the 6 months prior to the baseline. Then, in the follow-up survey, respondents were asked if the households had any of such experiences since they changed their cooking practices. Figure 5 illustrates that both main cook and her family have experienced significant improvements in their self-reported health. Based on their reports, experiences of burning reduced by 88%, eye irritation by 92%, coughing and sneezing by 85%, chest pain by 93%, shortness of breath by 89%, irritation of nose and throat by 89%. In addition, 76% of respondents also reported feeling more safe since adopting the Ecocina, with 12% reporting less safe. However, as noted earlier, such results are prone to self-report biases, and the time frame of using the Ecocina was only 2 months relative to the 6

months asked in the question. Nevertheless, results indicate that households perceive health improvements by adopting the Ecocina, leading to a positive experience using the stove and motivation for other households to adopt the Ecocina as well.

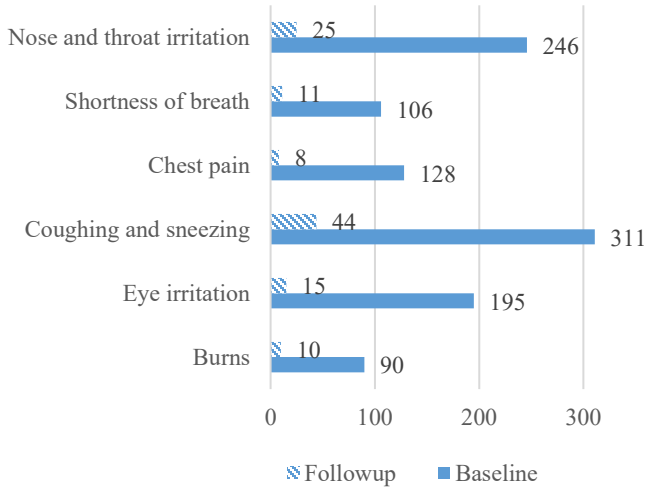

Fig. 5. Households self-reported health and safety risks before and after adoption to Ecocina.

D. Social Impact

This project also carried out a self-report social impact study to capture how the introduction of the Ecocinas affected social trust. For this purpose, the changes in households' attitude regarding some influential actors in the community before and after intervention were measured. Influential actors include doctors, teachers and NGOs/government officials. Figure 7 (a-c) illustrates that the level of trust to such actors has improved from baseline to follow-up. This indicates that the bonding social capital (i.e. level of trust) as reported by the households has improved after the stove intervention.

V. Conclusions and Future Work

This study evaluated the impact of introducing improved cookstoves in 390 households in rural Honduras using a comprehensive approach. In the study at least 1,765 community members were affected by introducing Ecocina, nearly 40% of whom are children 17 years old or younger. Overall, households' experience using the Ecocina was satisfactory because nearly 85% of participant households were cooking their main meals with this stove every day two months after receiving it. The households identified burning less firewood than traditional stoves and open fire along with saving time for cooking practices as major benefits of the Ecocina. In 80% of the houses the Ecocina was visible with signs of recent usage.

For 80% of the beneficiaries, the level of the effort for cooking, the time it takes, and firewood consumed was reported as decreased when using the Ecocina compared to their traditional practices, which was a traditional Plancha stove in 97% of the households. More than 98% of users stated that using Ecocina is easy or somewhat easy for cooking practices. For all but one user, the Ecocina was perceived to be equally (13%) or more safe (87%) than traditional methods. On average, the time

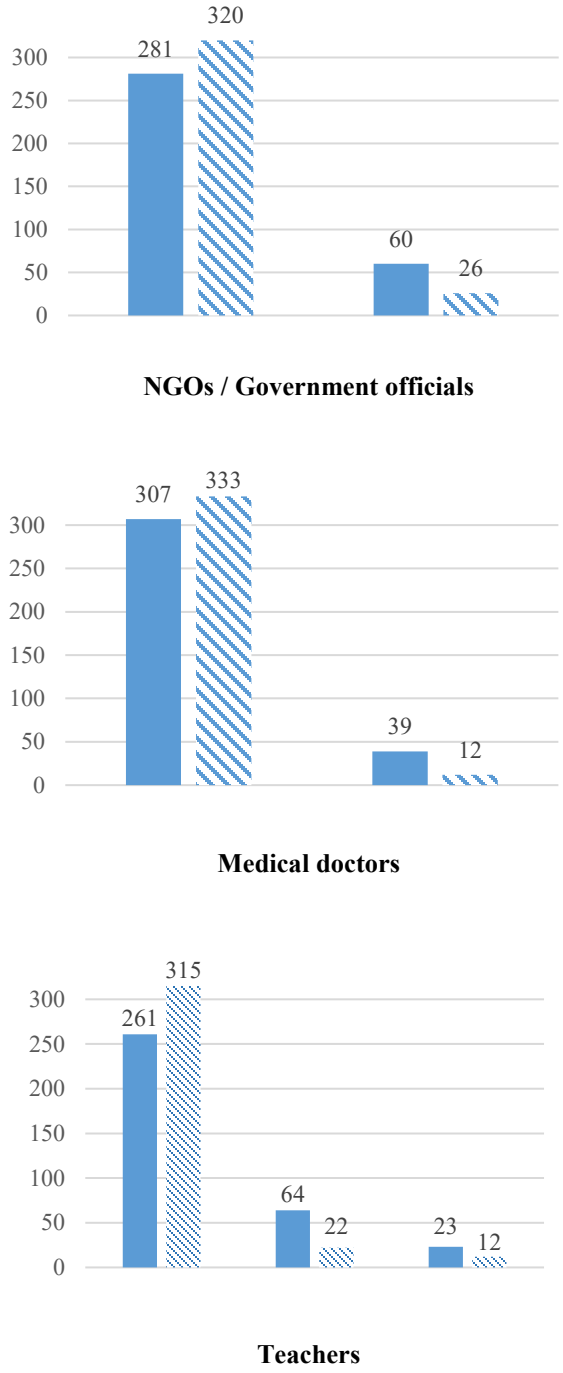

Fig. 6. Change in stated level of trust for NGOs/government officials, Doctors, Teachers from baseline to follow-up.
[Solid: baseline, hatched: follow-up]

for trips to collect firewood was reduced by 11.3%. Health and safety showed significant improvements, with 90% of respondents reporting 85-93% reductions in burns, eye irritation, coughing, sneezing, chest pain, and nose and throat irritation.

The considerable improvements that households reported regarding time saving, health and safety and firewood consumption may be overstated to some extent. Because self-

reported outcomes are known to be subject to bias, future work should include more objective quantitative evaluations through sensors and other rigorous monitoring techniques to verify these conclusions. In addition, to evaluate stove usage behavior over a longer time frame, future data collection is planned for two years after the initial intervention. Results of the long term study will provide insight for the design of effective and continuous replacement of traditional practices.

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